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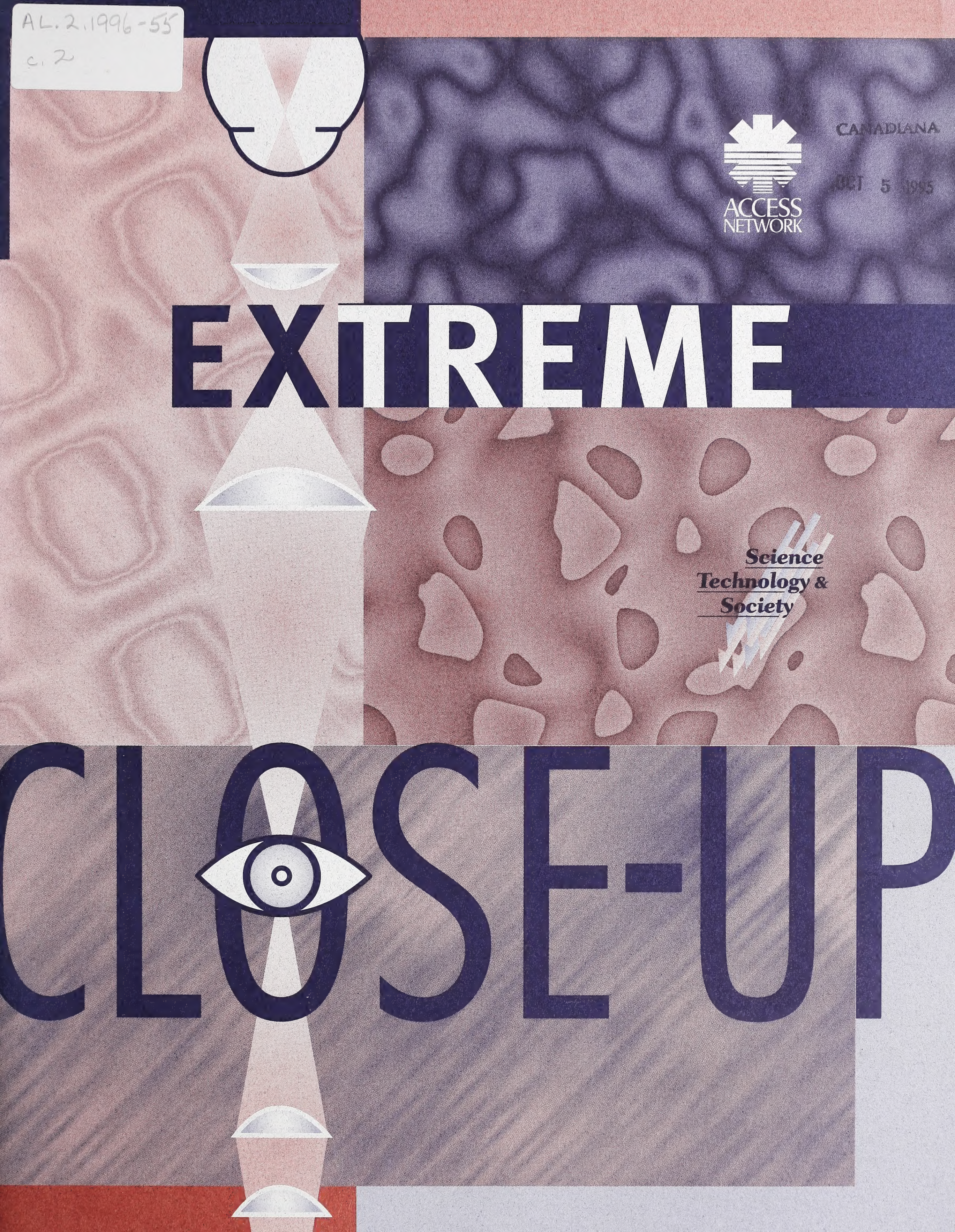

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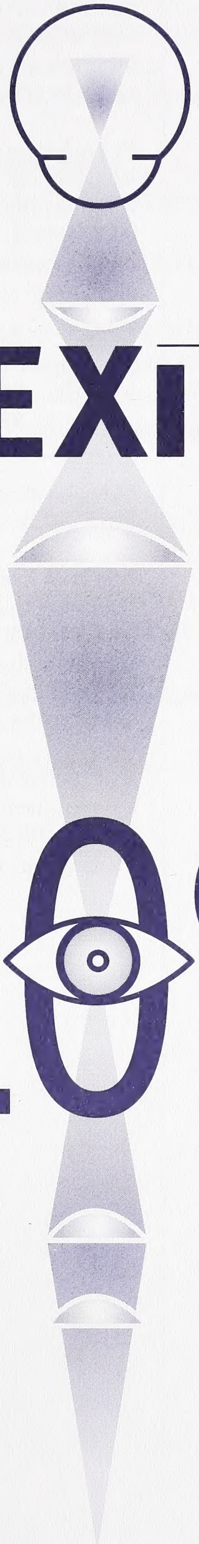

Science
Technology &
Society

The guide that accompanies **Extreme Close-up** of the Science, Technology and Society series was written by Helen Brisbin. Content consultants were Barry Edgar of Edmonton Public Schools, Rakesh Bhatnagar of the University of Alberta, and Craig Sherburne and Richard Sherburne of the University of Alberta.

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Table of Contents

The Science, Technology and Society Series 1
To the Teacher 1
Overview of *Extreme Close-up* 1

Microscopes 2
Early Microscopes 2
Resolution 2
Compound Light Microscope 3
Light Waves 4
Electron Microscope 5
Scanning Electron Microscope 7
Scanning Tunnelling Microscope 9
Confocal Laser Scanning Microscope 10

The Scientists 12
Dr. David Cass and Lory Sanders 12
Richard Sherburne and Dr. Diane Taylor 12

Applications for Microscopes 14

Suggested Questions for Research and Discussion 15

Bibliography 18

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The Science, Technology and Society Series

STS is an international science education movement. It represents the first significant change in the science curriculum in 25 years. The STS concept strives to broaden the scope of science education by integrating into science curricula accurate presentations of the nature of science, the nature of technology and the interactions of science and technology with each other and society. The video series provides illustrative examples of the relationships between science, technology and society.

The STS connections describe products and processes; environmental and ethical issues relating to the interrelationships among science, technology and society; how scientific knowledge develops and the influence of society on scientific and technological research; and science and technology related careers. The contexts are meant to be relevant to students' lives and also prepare students for life in a rapidly changing society in which science and technology play an important role.

To the Teacher

This video is intended for students in junior and senior high school who are using the microscope to study basic cell structure. The video shows how microscopy began and how the technology has evolved in recent years. By looking at the work of various scientists, we see applications for compound light microscopes, transmission electron microscopes, scanning electron microscopes, and the very new confocal laser microscope.

The video offers insights into how various models of microscopes work. It shows previously hidden worlds which scientists are bringing into ever sharper focus under the powerful eye of the microscope, and emphasizes the growing importance of microscopes in many fields.

Overview of *Extreme Close-up*

In 1938, two students at the University of Toronto, Albert Prebus and James Hillier, put together the first working model of the transmission electron microscope in North America. This represented a major evolution in the science of microscopy: one that scientists have been steadily building on ever since.

The electron microscope's ability to magnify specimens thousands of times has enabled us to study many aspects of the molecular world around us. Microscopes have become indispensable in almost every type of work—from food processing to police forensics, micro-surgery, and geological surveys. Microscopes extend the human eye, helping us to understand and explain natural phenomena.

This production should give students an appreciation for the capabilities of modern microscopes, their importance to society on a number of levels, and the many new frontiers that are opening up using microscopic research.

We look at the compound light microscope that is used in high school labs and see the role this instrument plays in more advanced research. We explore the capabilities of two types of electron microscope: the **transmission electron microscope**, and the **scanning electron microscope**. And we take a look at the latest development in light microscopes: the **confocal laser microscope**.

The video shows how science and technology advance hand-in-hand. For example, more powerful microscopes were developed as scientists gained a better understanding of light and electrons. Viewers will meet various scientists who work with microscopes, and see how these people are using advanced microscopic technology to achieve specific goals.

Microscopes

Early Microscopes

Glass was first manufactured in Egypt in 2000 B.C., and its magnifying powers may even have been recognized that long ago. We do know that at the time of the Roman empire, people were using lenses to magnify objects. By the 1200s, crystal lenses had been designed for use as spectacles. This was the beginning of a new branch of physics, known as **optics**. About 400 years later, lenses were put to new uses with the first versions of the telescope and compound light microscope.

In 1609, Galileo constructed the first astronomical telescope, which he used to study our solar system, and the stars around us. About 50 years later in Holland, an amateur scientist named Anton van Leeuwenhoek began experimenting with microscopes. In the course of his studies he made more than 200 microscopes, some of which were able to magnify specimens 270 times their original size. Van Leeuwenhoek was the first person to observe and document living cells. He called the single celled organisms he observed "animalcules". He also studied capillary circulation and red blood cells. The lenses used in early microscopes distorted the image so it was difficult to get a clear picture of cell structures.

The telescope and microscope are similar in that they both use lenses to enlarge the image of objects. The telescope magnifies distant objects, bringing the image closer to the human eye. The microscope magnifies tiny objects, making them appear larger so they can be seen by the human eye.

Resolution

The ability to magnify an object is one aspect of microscopy; **resolution** is the other equally important aspect. **Resolution** is the ability to recognize two objects as being distinct from one another and to **resolve** the distance between them: in other words, the ability to distinguish fine detail.

The human eye has a resolving power of about 0.1 mm. This means that the human eye can distinguish two objects as being separate from one another if the space between them is at least 0.1 mm.

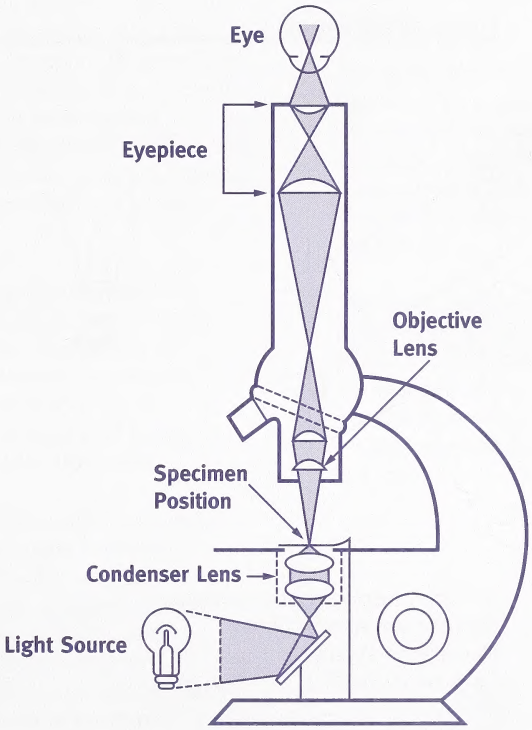
Resolution in the electron microscope is measured in **nanometres**. One nanometre is equal to one billionth of a metre.

Compound Light Microscope

At the same time that Anton van Leeuwenhoek was working with single lens microscopes, Robert Hooke, a 17th Century English scientist, constructed the first compound light microscope. The compound light microscopes found in every modern science lab operate in much the same way as Hooke's early models. Two lenses are used to enlarge the image. The *ocular lens* is close to the observer's eye, and the *objective lens* is close to the specimen. There are usually three objective lenses: low, medium and high. The objective lens magnifies the specimen itself, and the ocular lens magnifies that image.

A compound light microscope can magnify an object about 1000 times its normal size, with good resolution.

Compound Light Microscope

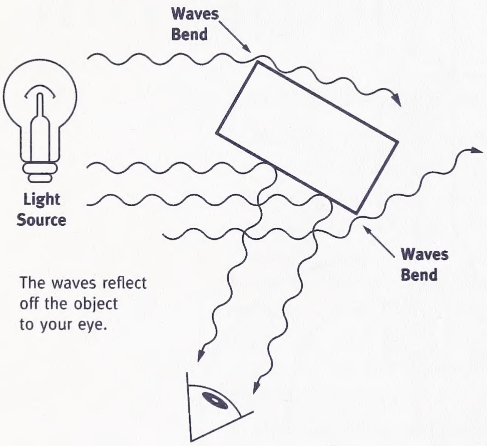


Light Waves

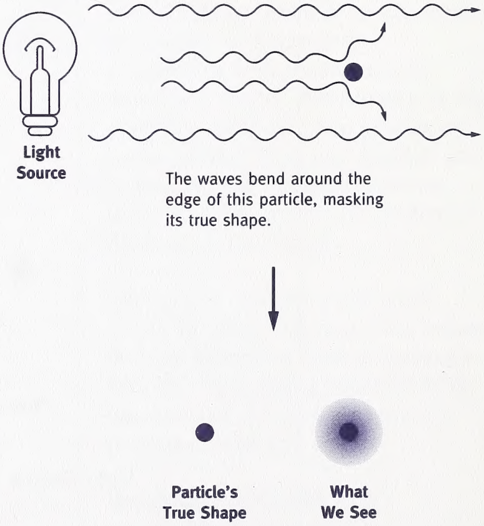
Light is a wave, and has a certain wavelength. When giving an image of an object, light microscopes are limited by the wavelength of the light. We are able to see things because light waves are reflected off objects, and then enter our eyes. When something is smaller than the wavelength of the wave striking it, the wave will bend around the edge of the object. This bending of the wave causes interference, which can mask the object's true shape, and limit resolution. The wavelength of visible light is between 400 to 750 nanometres. If we want to see something smaller than the wavelength of light, we must use another source with a shorter wavelength.

Electrons exhibit wave properties similar to visible light, but the wavelength of the electron is far shorter. While the wavelength of visible light is 400 to 750 nanometres, an electron wavelength is less than 0.1 nm. Therefore electron wavelengths are 4000 to 7000 times smaller than light wavelengths, depending on the voltage. (The higher the voltage, the shorter the wave.) This means that electrons enable us to resolve objects which are not visible using light.

Limits to Resolution



The waves reflect off the object to your eye.



The waves bend around the edge of this particle, masking its true shape.

You can't resolve anything smaller than the wavelength of the illumination source.
(λ = wavelength)

visible light: λ = 400-750 nm
(1nm = 1 billionth of a metre)

electrons: λ = 0.1 nm (approx.)

Electron wavelengths are 4000-7000 times smaller than light wavelengths, so electrons can resolve things that are many times smaller.

Electron Microscope

An electron microscope uses electrons rather than light to image a specimen. Although work was being done on the electron microscope in Europe in the 1930s, two Canadian scientists made North America's first working model in 1938. A similar model was built in the United States in 1939. Since then, the technology of electron microscopy has continually advanced.

Electrons are tiny subatomic particles that reside around the nucleus of an atom. In a **transmission electron microscope (TEM)**, a high voltage current removes outer electrons from a Tungsten atom, and accelerates the electrons down the column and through a very thin section of a specimen. Because the wavelength of electrons is so small, even molecules in air would interfere with the electron beam. For this reason, the electron beam must travel through a vacuum in the microscope.

The higher the voltage used to accelerate the electrons down the column of the microscope, the shorter the electron wavelength. Electron microscopes use an accelerating potential of between 20,000 to 1,000,000 volts.

When a charged particle moves through a magnetic field, its direction of motion can be altered. For this reason, electromagnets are used to focus the beam, just as lenses focus light waves in a compound light microscope. This enlarges the image produced by electrons when they strike a fluorescent screen, or a photographic plate if a permanent record of the image is needed.

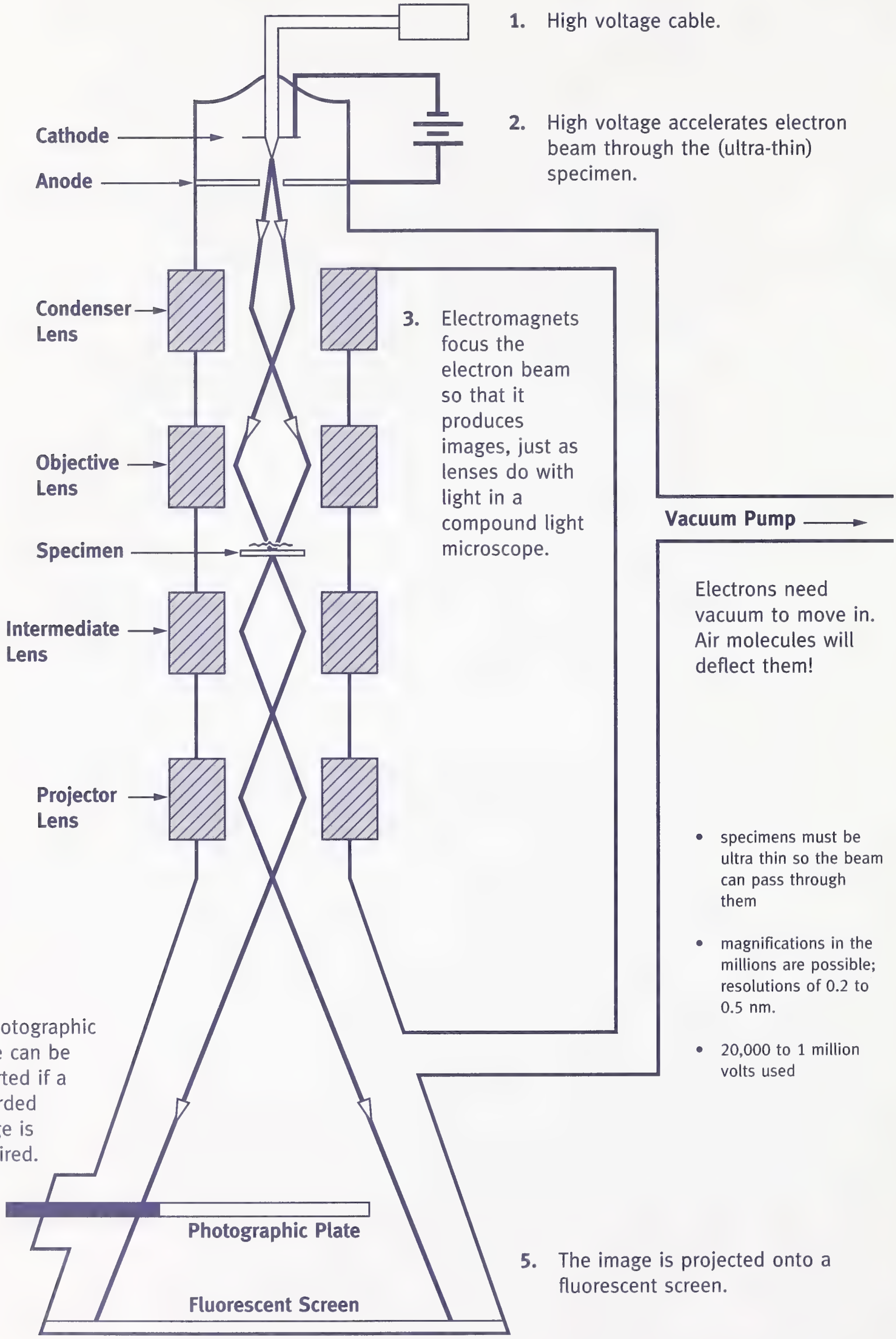
The transmission electron microscope transmits electrons right *through* the specimen, giving an image of the internal structure of the cell. Because cells are electron dense, the specimens must be sliced very thin. Specimens are mounted in a plastic embedding material for ease of cutting.

Electron waves are too short to be visualized by the eye. Therefore a phosphor-coated screen, much like those used in the first television screens, is placed in the path of the electrons. The phosphor is activated by the electrons as they strike the plate, and visible light is emitted, giving an image on the plate of the electron density of the sample. The electrons which do not penetrate the sample do not contribute to the image.

The lack of contrast in the image produced by a transmission electron microscope can be a problem; therefore an electron dense stain is often applied. Reading the image accurately is a skill that comes with experience.

The first transmission electron microscope was able to magnify samples 7000 times. Today's models are capable of magnifications greater than 300,000 times, and a resolution of between 0.2 and 0.5 nm.

Transmission Electron Microscope (TEM)



1. High voltage cable.
2. High voltage accelerates electron beam through the (ultra-thin) specimen.
3. Electromagnets focus the electron beam so that it produces images, just as lenses do with light in a compound light microscope.
4. A photographic plate can be inserted if a recorded image is required.
5. The image is projected onto a fluorescent screen.

Electrons need vacuum to move in. Air molecules will deflect them!

- specimens must be ultra thin so the beam can pass through them
- magnifications in the millions are possible; resolutions of 0.2 to 0.5 nm.
- 20,000 to 1 million volts used

Scanning Electron Microscope (SEM)

Developed in the 1970s, the SEM scans the surface topography of a specimen, producing a three dimensional image on a screen.

An electron beam is produced just as it is in the transmission electron microscope. The electrons are then passed through a series of magnetic lenses that focus the beam to a very fine point, 10 nm or less in diameter. This fine point of electrons, called a scanning probe, scans the surface of the specimen. The electrons reflected from the specimen, along with electrons released from the surface of the specimen, are captured by an electron detector and the number of electrons is counted. As the beam scans across the surface of the specimen, an image is formed. The brightness of any given point in the image is based upon the number of electrons counted at the corresponding point on the specimen. The image is viewed on a display unit very similar to a television screen. Since the number of electrons emitted depends on the surface features of the specimen, a three dimensional picture of the specimen can be produced.

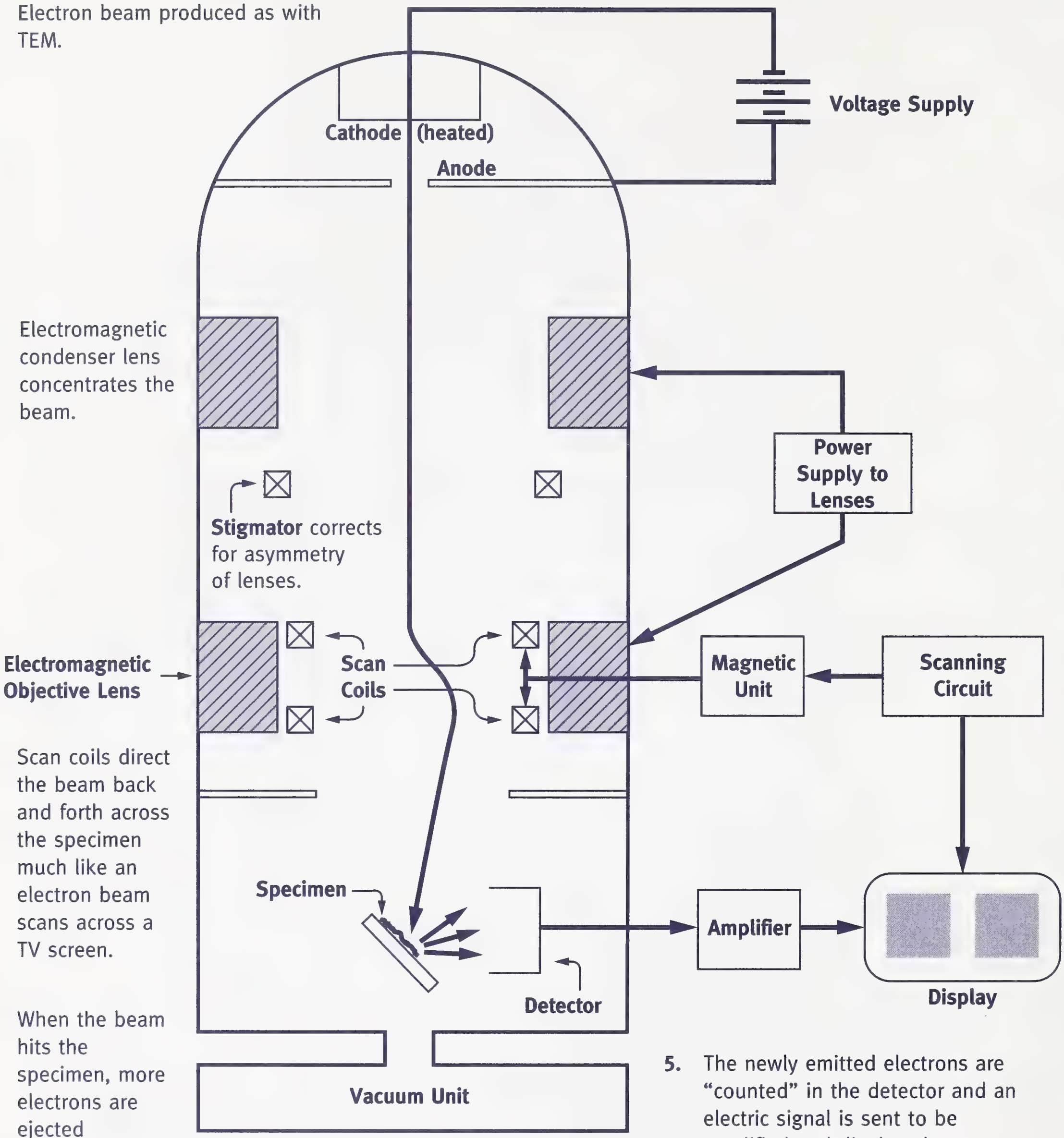
A scanning electron microscope can magnify a specimen to approximately 300,000 times. Its resolution and magnification are not as good as that of the transmission electron microscope, but improvements are constantly being made.

Earlier models of the scanning electron microscope used a high accelerating voltage to achieve maximum resolution, which could destroy biological specimens. Specimens were coated with particles of gold so they would conduct electrons from the sample, decreasing the sample destruction. But even though the gold coating was only 10 to 50 nm thick, it sometimes interfered with the viewing of fine biological structures. Using low voltage electrons, without special equipment and techniques, decreased the resolution.

But technology is improving. Current development includes a **low accelerating voltage** scanning electron microscope with **high resolution** scanning. This instrument gives an accurate image of the specimen without distortion caused by metal coating, and without destroying the specimen.

The two microscopes complement each other in many fields. For example, with the transmission electron microscope one is able to locate bacteria within cells, while the scanning electron microscope will show the area where a bacterium interacts with the cell. This allows researchers to study important details in host-pathogen interactions.

Scanning Electron Microscope (SEM)



1. Electron beam produced as with TEM.
2. Electromagnetic condenser lens concentrates the beam.
3. Scan coils direct the beam back and forth across the specimen much like an electron beam scans across a TV screen.
4. When the beam hits the specimen, more electrons are ejected according to surface features.
5. The newly emitted electrons are "counted" in the detector and an electric signal is sent to be amplified and displayed on a monitor.

The scanning circuit sends signals to the scanning coil (electromagnets) *and* to the display unit. This keeps the display monitor in sync with the scanning of the surface.

Scanning Tunnelling Microscope

The idea for the scanning tunnelling microscope has been around since the early 1900s, but only recently has the technology been in place to make it work. The first scanning tunnelling microscope was made in 1981 by two researchers at an IBM lab in Zurich. The researchers, G.K. Binnig and H. Rohrer, received the Nobel prize in 1986 for their work.

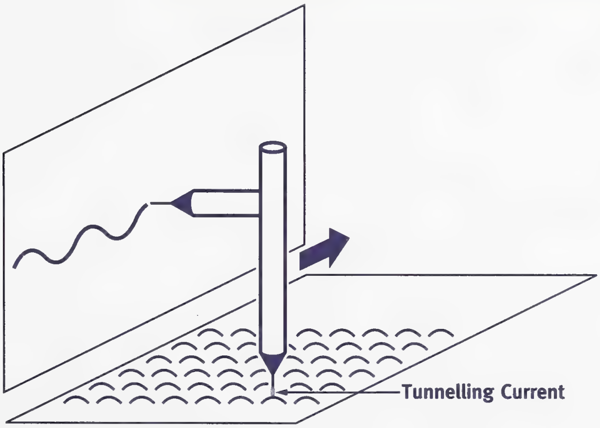
A probe on the scanning tunnelling microscope scans the surface of a specimen, sensing the distance between its tip and the surface. These distances are recorded and converted into a magnified image that is displayed on a screen. The image shows only the surface topography of the specimen.

The probe of a scanning tunnelling microscope has a tip that is only one atom thick. A differential voltage is applied between the probe and the surface of the specimen. The tunnelling of the electrons from the surface to the probe gives rise to a tunnelling current, which is relative to the distance between the surface and the probe. The image which results can show surface details of atomic size.

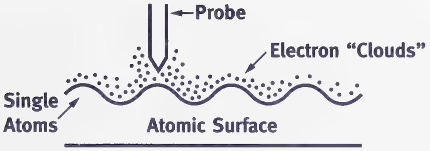
Today scanning tunnelling microscopes are used extensively in the computer industry. They can, for example, show the exact crystal structure of the surface of a silicon chip. This may lead to the development of even smaller chips in the future.

These microscopes are now used on an experimental basis in other sciences, such as biology.

Scanning Tunnelling Microscope (STM)*



1. Surface is scanned with a probe sensing the distance between its tip and the surface. The distances are recorded.
2. The probe's tip is nearly as small as one atom thick. The electrons at the surface of the atoms of the object to be scanned are located according to a probability distribution (dots). A "tunnelling current" occurs between the probe and the surface. The strength of this current varies with distance from the probe to the surface, and with the electron structure of the material involved.



* Invented in 1981 by G.K. Binnig and H. Roher at an IBM lab in Zurich. They won the 1986 Nobel Prize for it. Designed for looking at atomic surfaces.

* Can show details as small as one atom.

Confocal Laser Scanning Microscope

The confocal laser scanning microscope is a very recent breakthrough in the technology of microscopes. It allows scientists, by means of **optical sectioning**, to look within a cell, and examine different sections without cutting or damaging the specimen. It is therefore ideal for studying live specimens. The principle is similar to a scanning electron microscope, except that it operates with light rather than electrons.

Although objects smaller than the wavelength of visible light cannot be seen, this disadvantage is more than compensated for by the fact that the specimen can be viewed alive, and that sections of the specimen can be viewed as well.

A laser produces a beam of light which is directed to scanning mirrors. The beam is focused through microscope lenses, and scans the specimen. The specimen can be stained with fluorochromes, substances that fluoresce when excited with a certain wavelength of light. The beam excites the fluorochromes in the specimen. Light emitted from the excited fluorochromes travels back and is focused through a pinhole near the lenses' focal point (the confocal point). Photomultiplier detectors convert light to an electric signal which can be stored and manipulated. The signal is then converted into an image by a computer, which also controls the scanning of the sample.

Because it can be used to view live specimens, the confocal laser scanning microscope has great potential in biology, zoology, and medical research.

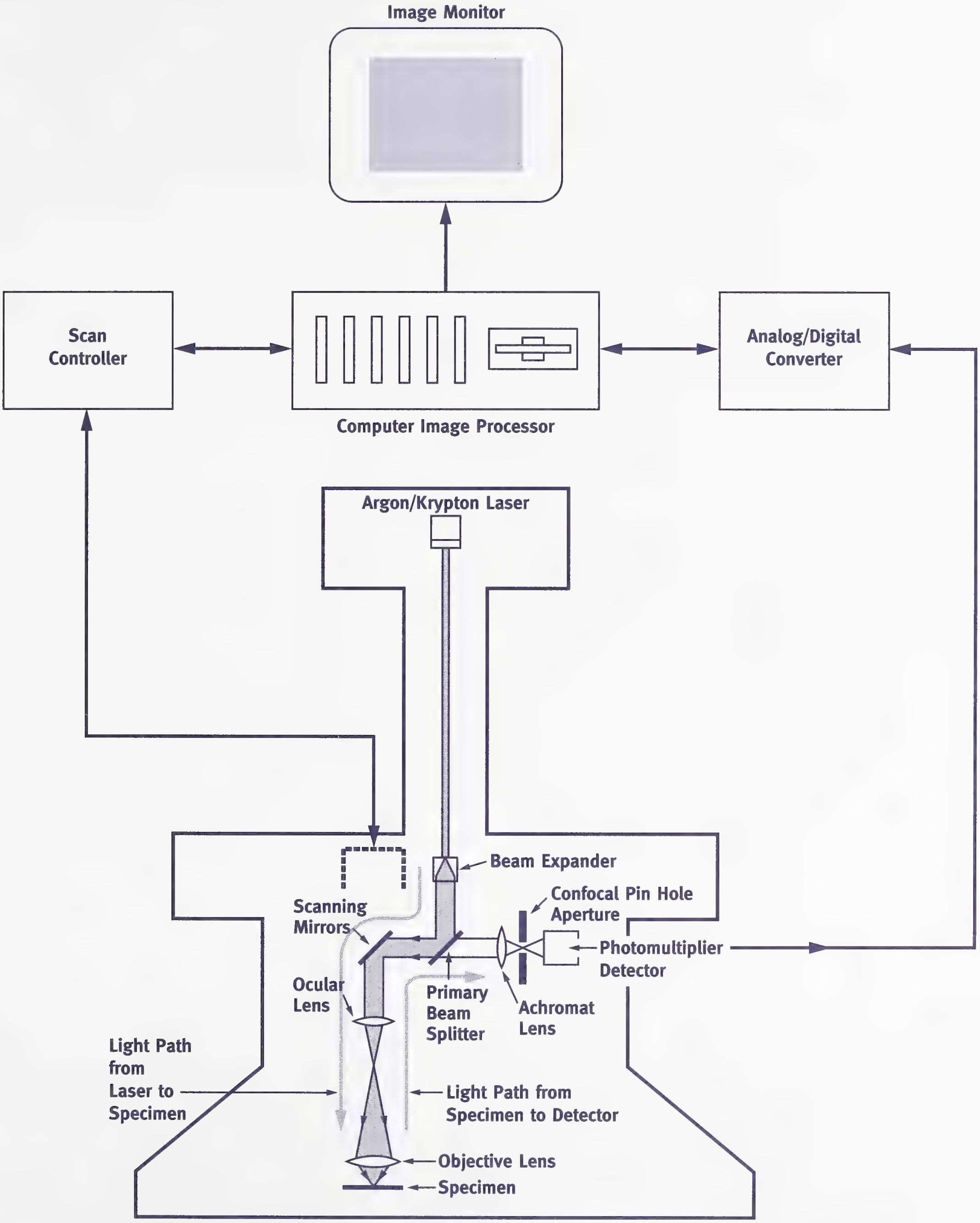


Image Monitor
Scan Controller
Analog/Digital Converter
Computer Image Processor
Argon/Krypton Laser
Beam Expander
Confocal Pin Hole Aperture
Scanning Mirrors
Photomultiplier Detector
Ocular Lens
Primary Beam Splitter
Achromat Lens
Light Path from Laser to Specimen
Light Path from Specimen to Detector
Objective Lens
Specimen

The Scientists

Dr. David Cass and Lory Sanders

David Cass, a biologist at the University of Alberta, and Lory Sanders, a student, rely on microscopes for their research and studies. In this program, they demonstrate how different microscopes can be used to reveal different perspectives on the structure of plant cells. Taking a section of leaf from a young pea plant, they examine it under a compound light microscope, transmission electron microscope, scanning electron microscope, and confocal laser microscope.

Before the specimen is viewed, it must be properly prepared, and this requires different procedures for the different types of microscope. Specimens are sectioned by a microtome, which is like a mini meat-slicer that cuts off extremely thin sections. Preparation for viewing under a compound light microscope involves "fixing" the specimen in paraffin, and staining it. Specimens must be imbedded in plastic for viewing under electron microscopes.

Dr. Cass explains that the **compound light microscope** is the basis for all microscopic work. Looking at the section of pea leaf under a compound light microscope, we can see the epidermal tissue, the underlying mesophyll cells and nuclei within these cells, as well as chloroplasts, mitochondria, and xylem. In order to have a look *within* the cells, we go to the transmission electron microscope.

The **transmission electron microscope** reveals the contents of cells. Under this microscope, we have a much closer view of the pea leaf specimen. Dr. Cass and Lory Sanders point out several interesting features, including the cell walls, two chloroplasts and the nucleus between them, vacuoles, Golgi apparatus, ribosomes, and a channel connecting one cell to another.

The **scanning electron microscope** gives us only the surface topography of the pea leaf specimen. It does not reveal images beneath the surface. Along with many of the organelles seen earlier, we can also make out guard cells. These are specialized epidermal cells that regulate gas exchange in a plant, allowing the plant to take in carbon dioxide and release oxygen.

In demonstrating the **confocal laser microscope**, Dr. Cass and Lory Sanders show how the microscope can optically section a specimen. This allows scientists to study any cross-section within a specimen, without having to physically cut it. For scientists who study living tissue, the confocal laser microscope marks a tremendous advance in technology. The ability to manipulate colours on the screen is an added asset in identifying various plant cells and their components.

Richard Sherburne and Dr. Diane Taylor

Richard Sherburne is a scientist in the field of Medical Microbiology and Infectious Diseases at the University of Alberta. His lab includes compound light microscopes, a transmission electron microscope, and a very advanced model of the scanning electron microscope. This scanning electron microscope is a low-voltage, high-resolution model that enables scientists to look at small biological structures, such as those arising from interactions between cells and pathogens.

Dr. Diane Taylor is a medical microbiologist who, along with colleagues at the University of Alberta, has been researching a bacterium that causes stomach ulcers. This is one of the many projects that Richard Sherburne is working on, using the microscope.

The ulcer-causing germ has been identified as the *Helicobacter pylori* bacterium, and has proven to be the cause of some, but not all, stomach ulcers. Scientists at the university are trying to discover what combination of antibiotics will be most effective in eliminating the bacteria. If the bacteria are not completely eliminated, the ulcers will eventually flare up again.

For Richard Sherburne, the *Helicobacter pylori* bacterium presents an intriguing and familiar problem. This bacterium is able to hide between cells, and remain dormant for years between flare-ups. Similar behaviour is suspected in the bacterium that causes pertussis, or whooping cough.

With the scanning electron microscope, Richard Sherburne can study the behaviour of the bacterium. By observing how it attaches itself to cells and hides within cells, he can gain a better understanding of how to treat this problem.

"Know your enemy" is a maxim for waging war on the battlefield and in the lab. The electron microscope allows scientists to study the previously hidden world of bacteria and viruses. When they can see how a pathogen interacts with healthy cells, scientists have a much better chance of finding a way to eliminate the pathogen.

Applications for Microscopes

As microscope technology becomes more advanced, the number of applications for this technology increases. Electron microscopes are used extensively in many industries, including the following:

Agriculture

- genetic engineering in developing new varieties of crops
- research into biological controls for pests

Computers and Advanced Electronics

- designing circuits
- constructing computer chips
- locating breaks in micro-circuits

Construction and Engineering

- examining metals for fatigue and stress fractures
- studying soil composition to assess stability

Food Research

- studying the microstructure of foods
- analyzing changes that occur when foods are processed

Geology and Mining

- studying the crystal structures of rocks and minerals.

Microscopes also play a vital role in many non-industrial areas:

Medical Research

- studying cell changes in diseases such as cancer
- diagnosing blood and viral diseases
- studying behaviour of bacteria and viruses

Every other field of scientific research

- studying the cellular and molecular structure of matter

Police Investigative Work

- DNA fingerprinting

Environmental Monitoring and Pollution Control

- analyzing the chemical compounds in air and water
- studying the effects of pollution on plants and animals

As microscopes become more refined, the list of possible applications expands. Both light and electron microscopes hold great potential for scientific research and discoveries. In the near future, light microscopes may be powerful enough to reveal viruses. The opportunity to study live viruses under a microscope, and see how they interact with healthy cells, would be a major step forward in medical research.

Despite the fact that scientific knowledge is increasing at unprecedented rates, scientists still have much to learn about plant and animal cells, bacteria, viruses, and the molecular structure of matter. Microscopy provides a path into unknown worlds, and holds tremendous potential for future scientific discoveries.

Suggested Questions for Research and Discussion

Forensic Science – Background

Forensic science is the collection and analysis of evidence found at the scene of a crime. Forensic scientists may specialize in any number of areas: enforcing environmental regulations, enforcing fishing and hunting regulations, or investigating criminal offenses in cooperation with the police department, fire department, or customs officials. A forensic scientist prepares reports for investigators. These reports become part of the case and may be used as evidence in court.

1. As part of the police investigative team, how would you use a compound light microscope to analyze evidence found at the scene of a crime? The evidence includes samples of hair, blood, fabric, and paint chips.

   Many different technologies are used in police forensic work, including gas chromatography, infrared spectroscopy, X-ray diffraction, and microscopy. A compound light microscope is used to examine samples of hair, blood, fabric and paint chips. A fairly low power is usually enough to reveal important evidence.

2. What is DNA fingerprinting, and how does it work?

   A far more sophisticated type of analysis is used to further identify the blood and possibly the hair samples. This is called "DNA fingerprinting". It represents the most significant advance in police work since conventional fingerprinting was developed.

   Scientists can take a tiny sample of tissue, blood, body fluids such as semen, or hair, if the root (the living portion) is intact, and establish a DNA fingerprint. An individual's DNA has a unique arrangement of nitrogen bases. In the laboratory, scientists take the DNA, cut it into smaller pieces with an enzyme, and transfer them to a nylon sheet. They then tag the DNA fragments with a radioactive probe that identifies the unique sections of the molecule. The nylon sheet is placed against X-ray film, and black bands appear where the radioactive probe has attached itself to the nitrogen bases. The result is similar to the bar code used on merchandise.

   Only identical twins will have the same arrangement of nitrogen bases in their DNA. If DNA from a sample taken at the scene of the crime matches a suspect's DNA, this would be enough evidence for a conviction in court. A DNA fingerprint provides positive identification of a suspect.

3. Do you need an electron microscope to produce a DNA fingerprint?

   DNA fingerprinting is a chemical procedure, and does not require an electron microscope. The discovery of DNA through the *electron microscope led to the development of this procedure.*

4. How is an electron microscope used in police forensic investigations?

   *A scanning electron microscope is used in police forensics when investigators need to study very tiny fragments of material. For example, a **gunshot residue analysis** involves taking swabs from the skin of a gunshot victim and a suspect's hands, and analyzing these under the scanning electron microscope. Heavy metals such as barium, antimony, and arsenic are present in gunpowder. The scanning electron microscope can identify tiny particles of heavy metals, and an X-ray spectrometer analyzes these particles to identify their composition.*

   When a suspect is found at the scene of a crime, swabs from the suspect's hands or gloves may prove that person fired a gun.

   The scanning electron microscope is also used to analyze tiny fragments of glass or metals, which may match tools or objects found at the scene of a crime.

Medical Science – Background

Physicians depend on laboratory work to assist them in diagnosing and treating patients. Medical researchers rely on microscopes to study the behaviour of bacteria, viruses, and healthy cells.

1. How is the compound light microscope used in blood analysis?

   Blood consists of plasma, which contains formed components such as erythrocytes (red blood cells), and leukocytes (white blood cells). Red blood cells supply and transport oxygen and carbon dioxide throughout the body and to and from the cells.

   White blood cells are divided into several categories. Some assist in clotting. Others function as a defense mechanism, destroying and mopping up foreign invaders. While the functions of several types of white blood cells are known, the role of others is not fully understood. Doctors can, however, obtain useful information from analyzing blood specimens under a light microscope.

   For example, during the course of infection there is a shift in the type of white blood cells which predominate in the blood stream. In many types of infection, especially bacterial, the total number of white blood cells increases. Some diseases cause a decrease in white blood cells. Using a microscope, scientists can calculate the percentage of each kind of white blood cell compared to a normal count. This helps the doctor determine what the cause of infection may be, and what treatment should be taken.

   The infectious agent itself may be seen in the blood sample under a light microscope, and identified by shape, size and staining characteristics.

   The presence and concentration of specific antibodies in the serum can also help the doctor to diagnose the illness.

2. Why are electron microscopes needed in order to conduct

more intensive medical research?

An electron microscope is able to achieve a much higher magnification. Many viruses and bacteria are too small to see using a compound light microscope, but can be seen using an electron microscope.

Some bacteria are able to elude the normal host immune system by invading cells and remaining within the intracellular environment for long periods of time, causing chronic long term infections. Examples of such bacteria are Mycobacterium tuberculosis, *the causative agent of tuberculosis (TB), and* Mycobacterium leprae, *the causative agent of leprosy.*

The electron microscope is often used to find the location of infectious particles within the cellular environment.

3. How does a scanning electron microscope complement the transmission electron microscope?

   A low-voltage, high-resolution scanning electron microscope enables researchers to study the surface topography of a specimen. The specimen may be sectioned to reveal bacteria hiding within a cell. Using the scanning electron microscope, researchers can see the manner in which bacteria attach themselves to a cell. This interaction between bacteria and body cells may provide scientists with a key to eliminating the bacteria.

4. A confocal laser microscope does not have the resolution of an electron microscope. Why is it considered to be such a breakthrough in technology?

   The confocal laser microscope has a unique ability to optically section a specimen. Scientists can take a piece of living tissue, and look at any cross-section of it without having to physically cut the specimen. It's possible to look at the layers inside a living cell without damaging the cell. The confocal laser microscope has great potential in biology and medical science.

Scanning Electron Microscopes – Pros and Cons

1. Is it possible for a scanning electron microscope, or a scanning tunnelling electron microscope to reveal what is beneath the surface of a specimen?

   No. The scanning electron microscope gives only the surface topography. Because the microscope scans only the surface, it shows an accurate picture of how the organism would appear to the human eye if we were able to see it. The scanning tunnelling microscope is valuable in the computer industry because it can be used to check the tiniest of semiconductors for flaws. It scans only the surface topography of the equipment.

Further Challenge

Have students select a science or enterprise which interests them. Ask them to research how recent advances in microscopy have affected work in this area.

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